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ELASTIC SCATTERING OF 1-100 eV
LITHIUM IONS IN HELIUM

WALTER J. EAGER

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Walter J. Eager



ELASTIC SCATTERING OF 1-100 eV
LITHIUM IONS IN HELIUM

by

Walter J. Eager

Lieutenant, United States Navy

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE
IN
PHYSICS

United States Naval Postgraduate School
Monterey, California

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ABSTRACT

As the initial phase in the determination of the interatomic potential function for the Lithium ion-Helium atom system the "effective attenuation cross section", Q , of a Li^+ beam in He gas was measured. The energy of the incident Li^+ ion was varied from about 1 to about 100 eV and the fraction of the collimated beam, which avoided scattering in its passage through a helium filled gas cell, was measured. The length of the scattering chamber was 7.76 cm and the gas pressures were in the region of 2 to 20 $\times 10^{-3}$ Torr. Two slit geometries were used: (0.0635) $\times$ (1.27) cm and (0.127) $\times$ (1.27) cm; the dimensions of the entrance and exit slit being the same in each case. The values of Q decreased with increasing energy and varied from about $3 \times 10^{-16} \text{ cm}^2$ to about $1 \times 10^{-16} \text{ cm}^2$.

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Date	Description	Amount
1890	Jan 1 Balance	100.00
	Feb 1	50.00
	Mar 1	25.00
	Apr 1	15.00
	May 1	10.00
	Jun 1	5.00
	Jul 1	2.50
	Aug 1	1.25
	Sep 1	0.62
	Oct 1	0.31
	Nov 1	0.15
	Dec 1	0.07
	Total	200.00
1891	Jan 1	100.00
	Feb 1	50.00
	Mar 1	25.00
	Apr 1	15.00
	May 1	10.00
	Jun 1	5.00
	Jul 1	2.50
	Aug 1	1.25
	Sep 1	0.62
	Oct 1	0.31
	Nov 1	0.15
	Dec 1	0.07
	Total	200.00

SYMBOLS

V_e	-	Lithium Ion Accelerating Potential (volts)
$\bar{E}$	-	Average Lithium Ion Energy in Beam (eV)
ΔE	-	Energy Spread of Lithium Ions in Beam (eV)
I^+	-	Positive Current to Ion Collector in high pressure ion gauge (ampere)
I^-	-	Negative Current to Electron Collector in high pressure gauge (ampere)
P_b	-	Pressure of Background Gases in Scattering Chamber (Torr)
P_{hb}	-	Pressure of Combination of Helium and Background Gases in Scattering Chamber (Torr)
P_h	-	Partial Pressure of Helium in Scattering Chamber (Torr)
N_h	-	Helium Particle Density (atoms/cm ³)
I_b	-	Lithium Ion Current Received at Ion Collector With Background Gases Alone in Scattering Chamber (ampere)
I_{hb}	-	Lithium Ion Current Received at Ion Collector With Helium and Background Gases in Scattering Chamber (ampere)
I_s	-	Lithium Ion Current Intercepted at Second Slit Frame (ampere)
Q	-	Lithium Ion - Helium "Effective Attenuation Cross Section" For Specified Value of Ion Energy (cm ² /molecule)
h	-	Subscript Referring to Helium
b	-	Subscript Referring to Background Gases
hb	-	Subscript Referring to Combination of Helium and Background Gases

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1. Introduction.

The scattering of atomic particles is one of the oldest and, in principle at least, one of the most direct ways of investigating the forces acting between such particles. In this experiment the interaction between a Lithium ion and a helium atom as a function of their separation is determined from the elastic scattering of a beam of Li^+ ions passing through Helium gas. Knowledge of such interaction forces in addition to their intrinsic scientific interest are also important in the understanding of high temperature properties of gases.

For such force law determinations the use of monoenergetic beam technique holds substantial advantage over other methods, such as analysis of gaseous transport and equation of state data. In the latter method, ambiguity is introduced by the necessity for averaging over the velocity distribution. Part of this advantage for beam technique is lost, however, in the averaging necessary to compensate for the variation of the minimum scattering angle along the beam path through the scattering chamber. Beam technique has a further advantage, that it can provide force law information at substantially smaller interaction distances than can conventional methods, due to the temperature limitations of containment materials.

The beam technique used consists essentially of:

- (1) directionally orienting and accelerating Lithium ions from a high temperature emitter, (2) obtaining a defined, collimated beam by use of two, well spaced slits, (3) passing the beam through a chamber containing background gas and through a final aperture slit, (4) measuring the pressure of the background gas, (5) collecting and measuring the background attenuated, ion beam, (6) admitting Helium to the chamber, (7) collecting and measuring the Helium plus background attenuated ion beam, (8) measuring the pressure of the Helium plus background gas, and (9) repeating the above measurements with ions of various energies.

From the ratio of the two ion beam currents, the pressures and the length of the scattering chamber the "effective attenuation cross section" is calculated for the beam geometry described by the particular slit width used. The farther advanced along the beam and the nearer to the beam's vertical center a Lithium ion is, the greater angle through which it must scatter to be "lost" and thus counted as a scattered ion. Therefore, the "effective attenuation cross section" must be taken through a complicated averaging operation to obtain the average total scattering cross section for each value of beam energy. From the average total scattering cross section as a function of beam energy, the interatomic potential function and force law can in principle be obtained.

In practice however, the analysis is complicated by two factors:

- (1) The existence of a limiting angle Θ_c such that for scattering events through an angle $\Theta < \Theta_c$ the quantum mechanical analysis must be used. Classical descriptions are only valid if $\Theta > \Theta_c$
- (2) Due to the complicated relation between the scattering angle Θ and the potential function $V(r)$ some a priori knowledge of the functional form of $V(r)$ is necessary even for the classical analysis of the problem.

Further details of the theoretical aspects of this problem are given in reference 1.

The work reported here represents the first phase of the experimental program. Its purpose was to complete the apparatus development, to make necessary measurements and to determine the "effective attenuation cross section" as a function of average beam energy. This was accomplished for two different slit widths.

2. Experimental Equipment

A schematic layout of the mechanical portion of the experimental apparatus is presented in figure 1A. The assembly is contained within the vacuum chamber described by figure 2. A background pressure of 5×10^{-6} Torr is maintained within the free space of the vacuum chamber with the ion emitter at operating temperature. The mechanical portion of the experimental apparatus (see figure 1A) consists of: (1) a thermal Lithium ion emitter (IE), (2) a gun (G) for accelerating the ions to uniform energy and forming them into a beam, (3) two separated slits (S_1 and S_2) for defining and collimating a uniform intensity

ion beam, (4) a scattering chamber (SC), into which Helium is admitted by metering valve (MV), and with provision for gas pressure measurements by ion gauge (IG), (5) an aperture slit (S_3) through which the "unscattered ions" pass to be collected, (6) a suppressor grid (SG) which suppresses secondary electron emission from the ion collector, and (7) the ion collector (C) which collects the "unscattered portion" of the ion beam for measurement. Referring to figure 1B, a precision micro-micro ammeter is used to measure the current of "unscattered ions" (I_b and I_{hb}). A second micro-micro ammeter is used to measure the ion gauge ion current (I^+), while a standard micro ammeter measures the ion gauge electron current (I^-). A precision, regulated, DC supply with discrete settings applies the desired accelerating potential to the electrode, E.

Details of the Lithium ion source are presented in Appendix A, while those of the beam collimating and scattering unit appears in Appendix B.

3. Experimental Procedure

A. Preliminaries

Throughout the experiment the background pressure in the free space of the vacuum chamber was maintained at approximately 5×10^{-6} Torr.

Power input to the Lithium ion emitter filament (see figure 1B) was maintained above 66 watts, corresponding to a minimum emitter surface temperature of 1000°C , as previously

determined by optical pyrometer measurements. Figure 5, a characteristic curve for the type of emitter used, indicates 100% Lithium ion emission at this temperature. No indication of a decrease of emitter surface temperature during Helium input to scattering chamber was noted. In obtaining attenuation data the beam accelerating potential was varied over as wide a range as possible. The limit was established by beam instabilities on the low side and excessive leakage currents to ground on the high side, (see figure 1B). Discrete DC supply voltage settings were purported to be accurate to $\pm .1\%$ above 5 volts. Apparently, AC leakage from the emitter filament upset this stability, however, and it was necessary to measure the applied voltage with a precision voltmeter during run number 1. During run number 2 the preset accelerating potentials were checked and found to be correct.

There was no indication that the ion gauge contributed to or affected the Lithium ion beam, so it remained in operation throughout each run. However, the vacuum system ion gauge was secured during the runs. The calibration of the ion gauge appeared to depend on the electron current (I^-), so it was maintained near 40 micro amperes during pressure measurements of run 2. This was accomplished by adjustment of filament voltage, prior to reading pressure.

To clear the Helium supply system of air the Helium was metered in, raising the vacuum system pressure to 5×10^{-5} Torr for 15 minutes.

The suppressor grid (SG) was maintained at negative 40 volts.

B. Lithium Ion Current Measurements

Background pressure was achieved in the scattering chamber (SC) by closing the Helium metering valve (MV) and opening the scattering chamber port. Referring to figure 1B the following sequence of operations was used:

- (1) Set and measure beam accelerating potential, V_e .
- (2) Measure I_s , the ion current intercepted by second slit frame (S_2).
- (3) Adjust ion gauge filament voltage such that electron collector current, I^- , is approximately 40 micro amperes and measure ion and electron collector currents (I^+ and I^-), simultaneously.
- (4) Measure I_b , the ion current received at the ion collector (C)
- (5) Close chamber port and open metering valve (MV) such that ion current is reduced to approximately 70% of its value in (4) above and measure I_{hb} .
- (6) Adjust ion gauge filament voltage such that electron collector current, I^- , is approximately 40 micro amperes and measure I^+ and I^- , nearly simultaneously.
- (7) Measure I_s as in (2) above.
- (8) Close metering valve (MV), and open chamber port.
- (9) Set V_e to an increased value and repeat (1) through (9) for the range of V_e .

Data was obtained as indicated above using two distinct slit sizes: .050 x .500 inches (run 1) and .025 x .500 inches (run 2). These data with calculations are listed in Tables I and II, respectively.

4. Calculations and Results

Tables I and II list beam attenuation data and calculations for experimental runs 1 and 2, respectively, corresponding to slit dimensions of 0.050 x 0.500 inches and 0.025 x 0.500 inches respectively.

An important step in the determination of the interatomic potential function for the Lithium ion-Helium system is the determination of the average value, $\overline{S(\Theta_0)}$, of the "total" scattering cross section, which is defined by:

$$S(\Theta_0) = 2\pi \int_{\Theta_0}^{\pi} \sigma(\theta) \sin \theta \, d\theta$$

where $S(\Theta_0)$ is the cross section for scattering through angles larger than Θ_0 for a specified energy, incident particle, and $\sigma(\theta)$ is the corresponding differential scattering cross section. To obtain the average of $S(\Theta_0)$ it is necessary to first calculate from the data listed in tables I and II, a quantity which has been referred to as the "effective attenuation cross section" and denoted by Q . Q would in fact be $S(\Theta_0)$ if a practical beam geometry could be found in which each interacting particle had to scatter through the same minimum angle, to be counted as a scattered particle. It should be noted that the geometry of this experiment as revealed by figure 1A is not this ideal geometry. Therefore, Q must be obtained and averaged over the beam geometry to obtain $\overline{S(\Theta_0)}$. The object of this phase of the work is to obtain Q as a function of incident particle energy for Lithium-Helium interactions.

TABLE I
DATA AND CALCULATIONS

Run 1 (slits: 0.050 x 0.500 inches)

V_e	I^+	I^-	I_b	I_{hb}	I_s	N_h	Q	$\bar{E}$
volts	amp. $\times 10^{-10}$	amp. $\times 10^{-6}$	amp. $\times 10^{-10}$	amp. $\times 10^{-10}$	amp. $\times 10^{-10}$	cm^{-3} $\times 10^{14}$	cm^2 $\times 10^{-16}$	eV
2.3	9.43	43.7	.246		28.7	1.682	3.43	1.6
	125	39.2		.162	29.5			
4.0	9.93	45.8	.325		31.0	1.830	3.76	3.0
	145	41.8		.207	33.5			
9.1	9.35	41.1	.400		40.0	1.311	3.38	7.5
	113	45.5		.283	39.8			
14.1	8.20	33.8	.535		46.1	1.441	3.31	12.7
	120	43.9		.380	47.3			
19.8	8.70	37.3	.695		53.5	1.557	2.87	18.3
	102	34.2		.498	54.0			
25.1	8.80	36.9	.890		60.2	1.696	3.28	24.1
	138	43.0		.598	62.0			
30.9	8.50	36.1	1.10		68.5	1.691	3.43	30.0
	155	48.5		.700	68.0			
40.0	10.8	49.7	1.38		78.5	1.753	3.06	38.9
	134	40.1		.920	79.0			
79.6	10.2	47.1	3.24		138	2.278	2.59	79.6
	181	42.1		2.06	138			
89.2	8.8	39.7	3.70		146	2.081	2.69	89.7
	157	39.8		2.42	147			
99.8	10.4	48.8	4.15		156	2.400	2.74	100.3
	192	42.3		2.54	158			
109.5	10.0	47.4	4.50		160	1.888	2.62	110.7
	151	42.3		3.10	161			
119.7	10.0	46.0	5.00		168	2.140	2.58	121.2
	128	31.9		3.35	172			
129.6	10.0	45.5	5.45		179	1.978	2.41	131.6
	166	44.4		3.80	180			
54.7	9.50	41.8	2.12		108	1.750	3.02	53.8
	140	42.1		1.43	109			
69.3	9.50	40.8	2.77		127	2.144	2.56	69.0
	141	35.0		1.86	130			
79.8	9.95	47.0	3.15		141	1.178	2.25	79.8
	92.5	41.5		2.66	146			
79.8	10.3	49.5	3.45		142	.930	2.86	79.8
	80.0	45.0		2.87	145			

TABLE II
DATA AND CALCULATIONS

Run 2 (Slits: 0.025 x 0.500 inches)

Ve	I ⁺	I ⁻	I _b	I _{hb}	I _s	N _h	Q	$\bar{E}$
Volts	amp x10 ⁻¹⁰	amp x10 ⁻⁶	amp x10 ⁻¹⁰	amp x10 ⁻¹⁰	amp x10 ⁻¹⁰	cm ⁻³ x10 ¹⁴	cm ² x10 ⁻¹⁶	eV
20	16.3	41.1	.100		145	1.980	3.25	18.7
	150	39.9		.066	158			
	15.5	40.7	.107		160			
25	15.3	41.5	.206		235	2.055	2.50	24.1
	156	40.1		.140	245			
30	14.1	40.3	.214		322	5.325	1.127	29.0
	400	40.0		.136	323			
35	13.1	40.3	.275		444	4.940	1.036	34.0
	365	39.2		.191	455			
40	12.5	40.4	.384		584	4.410	1.324	38.9
	335	40.6		.250	595			
45	12.4	41.1	.498		735	4.745	1.131	44.0
	361	40.7		.333	741			
50	11.5	39.3	.582		894	5.720	1.013	49.0
	439	40.8		.380	910			
55	11.0	39.1	.695		1088	5.980	.907	54.1
	440	39.2		.456	1080			
60	11.0	40.9	.800		1270	3.375	.741	59.3
	260	40.9		.670	1290			
65	10.6	39.5	.942		1485	5.885	.809	64.6
	442	40.3		.654				
70	10.4	41.4	1.09		1690	6.740	.778	69.8
	518	41.0		.720	1670			
80	10.3	40.4	1.52		2100	6.445	.847	80.1
	498	41.3		1.00	2100			
90	9.8	38.0	1.94		2550	6.100	.790	90.3
	458	39.7		1.33	2530			
100	9.9	38.0	2.54		3003	5.915	.936	101.0
	465	41.8		1.66	3000			

To derive the relation of the data of this experiment to Q , it was necessary, in addition to the ideal geometry assumption, to assume that the Lithium ion interacts with Helium only once in traversing the scattering chamber. This assumption was justified by the experimental procedure of limiting the Helium pressure such that the mean free path for the Lithium ion in Helium was a minimum of five times the scattering chamber length. Then the basic attenuation relation is:

$$dI_{hb} = -I_{hb} (Q_h N_h + Q_b N_b) dx$$

where

- dI is the change in beam current in length element dx
- I is the beam current incident on the element dx
- Q is the attenuation cross section (effective)
- N is the number of target particles per unit volume
- h is subscript referring to Helium gas
- b is subscript referring to background gas
- hb is subscript referring to the combination

Integrating from $x = 0$ to $x = L$, this basic relation becomes

$$\frac{I_{hb}}{I_0} = e^{- (Q_h N_h + Q_b N_b) L}$$

This ratio represent the attenuation factor for a beam of current value, I_0 , incident upon the volume of combined Helium and background gases contained in the attenuating Helium path length, L . Subtracting, then dividing by the attenuation factor for background gases alone, the following relation is obtained:

$$\frac{I_{hb}}{I_b} = e^{-Q_h N_h L}$$

which can be solved for Q_h as:

$$(1) \quad Q = - \frac{1}{N_h L} \ln \frac{I_{hb}}{I_b}$$

Q , then, is the effective attenuation cross section for a specified incident particle energy in Lithium ion-Helium interactions, and is obviously a function of the slit geometry. N_h is the Helium particle density in the scattering chamber during measurement of I_{hb} . I_{hb} is ion current measured at ion collector (c) with the combination of Helium and background gases in the scattering chamber while I_b is the ion current measured with background gas alone in the scattering chamber.

The Helium particle density N_h , was obtained from the perfect gas law, using an assumed temperature of 296°K . The computational formula was:

$$N_h = 0.326 \times 10^{17} \frac{P_h(\text{Torr})}{\text{Torr}} \frac{\text{atoms}}{\text{cm}^3}$$

Where P_h is the partial pressure of Helium obtained by subtracting the background pressure P_b (measured coincident with I_b) from the total pressure of Helium and background gases, P_{hb} (measured coincident with I_{hb}). Values for P_{hb} were obtained from an ion gauge calibration curve (figure 6) using the appropriate ion-electron collector current ratios, I^+/I^- . P_b was obtained from a calibration curve for Nitrogen.

The ion current intercepted by the second slit frame was found to tend to larger values when Helium and background gases were in the scattering chamber than when there was background alone. This would indicate that significant helium densities were appearing ahead of the scattering chamber. During preliminary runs it was found, however, that a similar increase was occurring at the slit nearest the emitter(s_1) and also that this tendency toward larger values was reversed when the accelerating potential was being decreased between sets of measurements rather than increased. It must therefore be concluded that these changes are due primarily to time dependent changes in the incident beam. Since these changes were monotonic for each set of measurements values of I_{hb} were corrected by a factor $(I_s)_b/(I_s)_{hb}$.

Since no scattering by Helium in advance of the scattering chamber could be detected, L , the attenuating Helium path length was taken to be the length of the scattering chamber (3.02 inches or 7.76 cm.). Then using the appropriate values of L , N_h , I_b and corrected I_{hb} , values for Q_h were obtained from equation (1) for each of the values of beam accelerating potential.

Although obtained at lower emitter temperatures, Table III provides a relation of average beam energy $\bar{E}$ to the accelerating potentials. This relation was used in determining average beam energies corresponding to values of Q_h . Table III also shows

TABLE III

(Extracted from Reference 2)

Average Beam Energies and Energy Spread

V_e (volts)	T ($^{\circ}\text{C}$)	$\bar{E}$ (ev.)	ΔE (ev.) (.25-.75)	ΔE (ev.) (.10-.90)
1.6	795	1.2	0.7	1.2
2.0	820	1.3	0.3	0.5
2.0	795	1.5	0.3	0.9
3.0	790	1.9	0.3	0.5
3.0	800	2.4	0.2	0.4
5	800	3.95	0.4	0.6
10	800	8.4	0.5	1.0
15	805	13.4	0.6	1.3
15	805	13.9	1.1	1.9
25	810	24.1	1.8	3.2
50	810	49	3.0	6
100	810	101	5.5	11

the approximate limits of beam energy spread about the average. These data were obtained by taking the difference between values of decelerating potential which reduced ion current to 90% and 10% of their maximum values, as well as 75% and 25%.

Effective Lithium ion-Helium attenuation cross section as a function of average ion energy is plotted in figure 7 for run 1 (slits: 0.050 x 0.500 inches) and in figure 8 for run 2 (slits: 0.025 x 0.500 inches)

The major source of error in the determination of attenuation cross section as a function of average ion energy was the determination of the Helium plus background gas pressure (P_{hb}) from which Helium particle density (N_h) was obtained. The ratio of ion gauge positive current to electron current (I^+ / I^-) could be determined within $\pm 1.5\%$. No fluctuations in the quantity due to real Helium plus background pressure fluctuations could be observed. The error in reading the calibration curve for P_{hb} and P_b contributes additionally such that the Helium particle density (N_h) could be determined only within a maximum random error of $\pm 3\%$. The ion current ratio (I_{hb} / I_b) could be determined with $\pm 1\%$. There was, however, an increase in the incident beam current with time which introduced a variable, systematic error. To correct for this I_{hb} was multiplied by the ratio of the ion current intercepted by the second slit frame (I_s) immediately before the I_b and after the I_{hb} measurements: that is, corrected I_{hb} equals $I_{hb} (I_s)_b / (I_s)_{hb}$.

Since there was variability in the timing of these measurements, a random error was introduced. At only one point did this correction exceed 4%. The maximum random error in $\ln (I_{hb} / I_b)$ is then estimated to be $\pm 2\%$. Summing the errors in N_h and the logarithm term the random error in the attenuation cross section (Q) is estimated to be within $\pm 5\%$.

Several points in run 1 (figure 7) have a greater than 5% departure from the curve. Most of this deviation was due to an apparent ion gauge calibration dependence upon the ion gauge electron current (I^-). This is confirmed by figure 9, which is an intercalibration of the ion gauge used with one of identical type. When I^- was held to $40 \pm .9$ micro amperes the inter calibration was a straight line. The point scatter shown was due to as little as ± 5 micro amperes deviation in I^- . During run 2, I^- was held to 40 ± 1.8 microamperes. The excessive departure of points in run 2 (figure 8) at and above 65 eV was due to surface charging of the slits. The deviated points at 29 and 34 eV are associated with high Helium particle density in a high cross section energy range; that is, comparatively small mean free path.

A systematic error is introduced by the inherent error in pressure calibration in the micron range. The ion gauge calibration curve (figure 6) is considered to be accurate within 30%. Thus, the attenuation cross section curves presented in figures 7 and 8 may be displaced from the actual by as much as 30%.

5. Discussion and Summary

As a first step in the determination of the interatomic potential function for the Lithium ion-Helium atom system, the "effective attenuation cross section", Q , has been experimentally determined as a function of the energy of the incident Li^+ ions. Since a total elastic scattering cross section will be derived from this data, it is of interest to consider any competing reactions which might also remove Lithium ions from the beam. The most obvious reaction is charge transfer, in which a Li^+ ion is converted to a neutral Lithium atom and, thus, is "removed" from the beam. Due, however, to the very large difference in ionization potentials of Li and He (19.2 eV) the cross section for the reaction:



is insignificantly small for ion energies utilized in this experiment. Similarly other inelastic scattering events, which might interfere with the determinations of this experiment, are small compared to the elastic scattering cross sections at the energies utilized.

As can be seen from figures 7 and 8, both the order of magnitude of Q (a few times 10^{-16} cm^2) and the energy dependence appear reasonable. Further, it is expected that the

cross sections for the narrower slits would decrease more rapidly with increasing energy than that for the wider slits. This trend is also observed. It does seem surprising, however, that the rate, at which cross sections decrease with increasing energy, differ as much as is shown in figures 7 and 8. An explanation for this discrepancy, if indeed it is a discrepancy, is not possible at this time and must await further analysis of the results.

In summary, this phase of the experimental program determined the "effective attenuation cross section", Q , as a function of average incident ion energy, $\bar{E}$, for two geometries, distinct by virtue of slit sizes: Run 1 (0.050 x 0.500 inches) and Run 2 (0.025 x 0.500 inches). The results are presented in figures 7 and 8. Maximum random error in these attenuation cross section values is estimated to be $\pm 5\%$. A maximum systematic error in the results of 30% may result from inherent errors of ion gauge calibrations in the pressure range of 10^{-3} Torr.

FIGURE 1A

EXPERIMENTAL APPARATUS SCHEMATIC

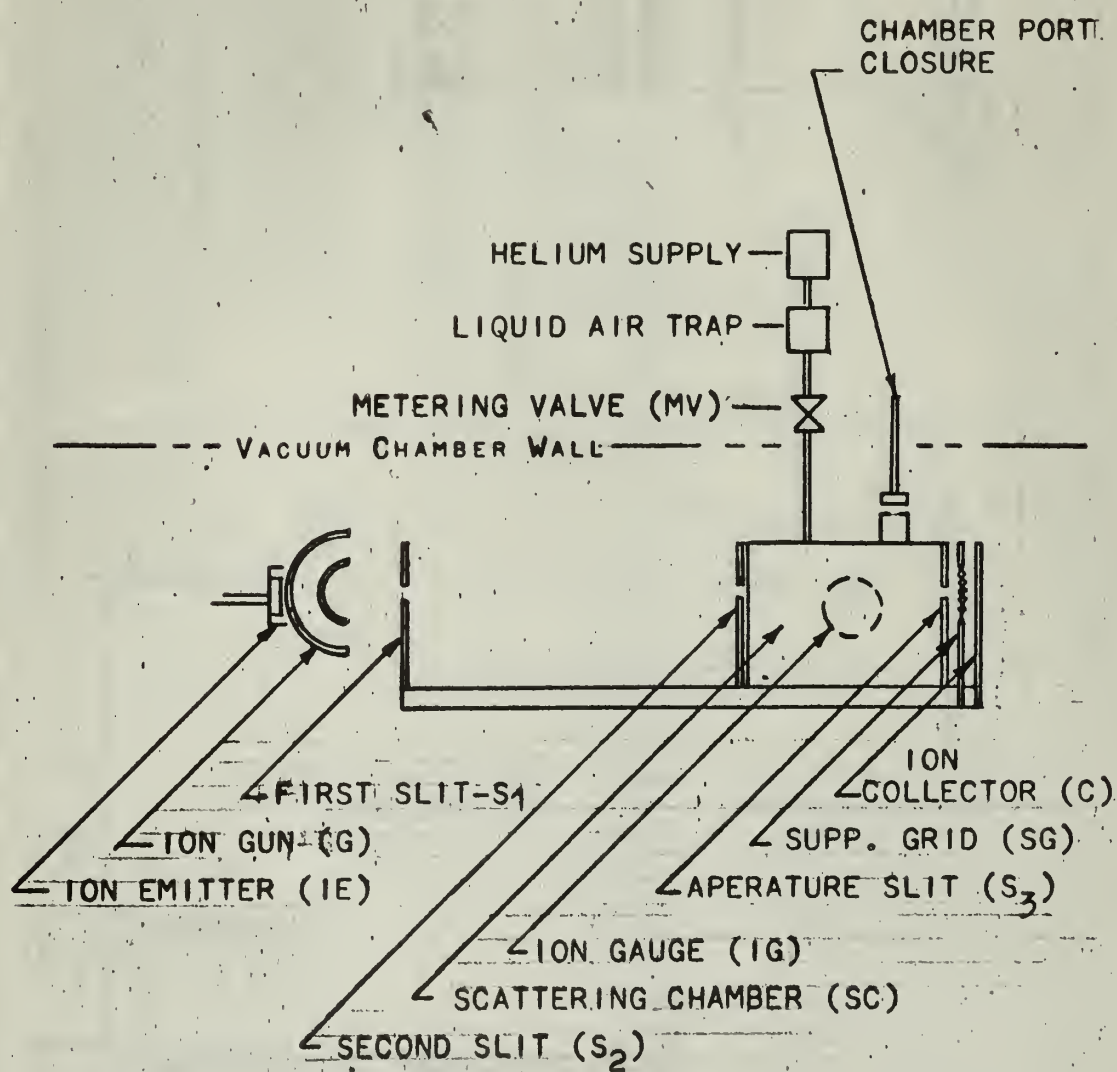


FIGURE 1B

EXPERIMENTAL APPARATUS SCHEMATIC - ELECTRICAL

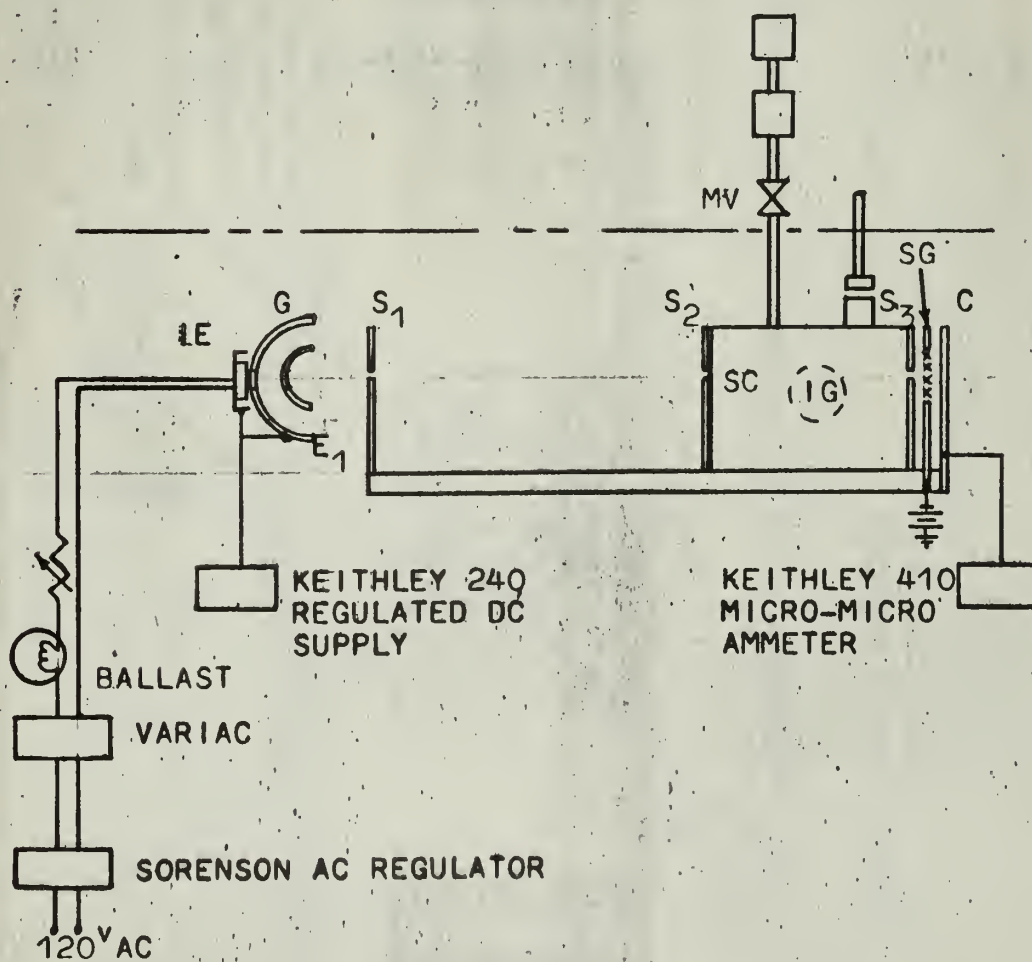
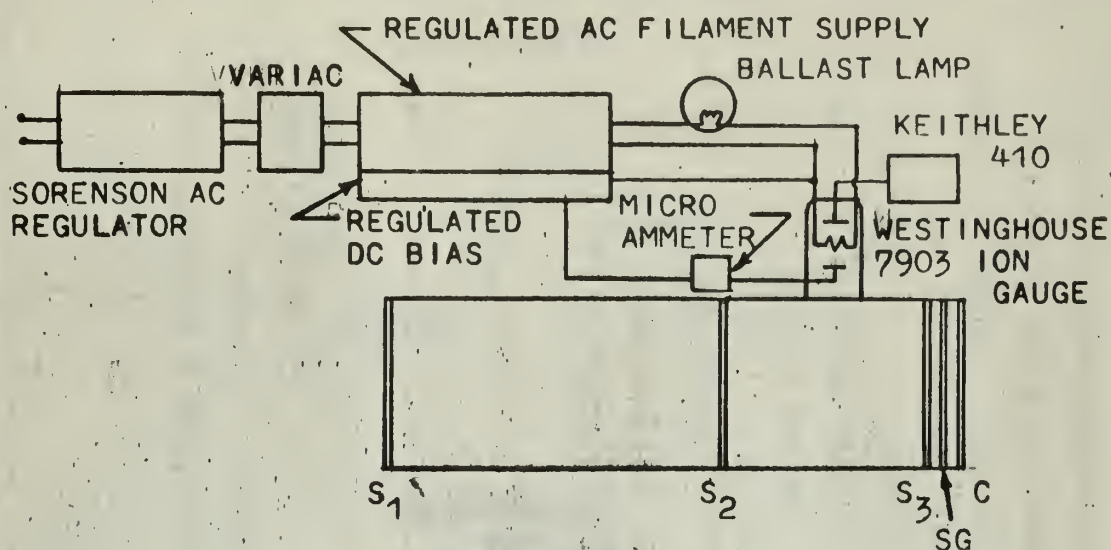


FIGURE 2

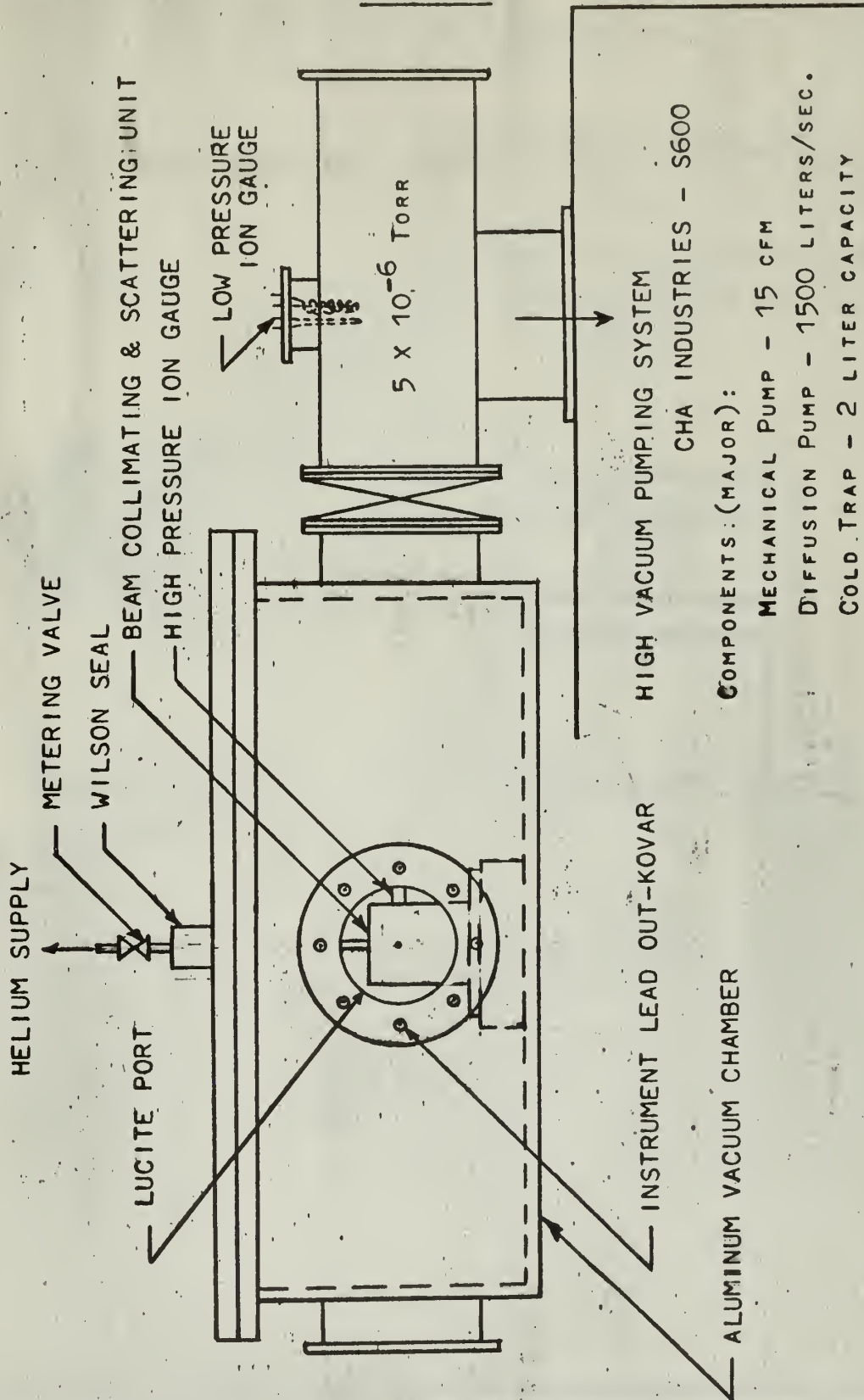


FIGURE 3
LITHIUM ION BEAM SOURCE

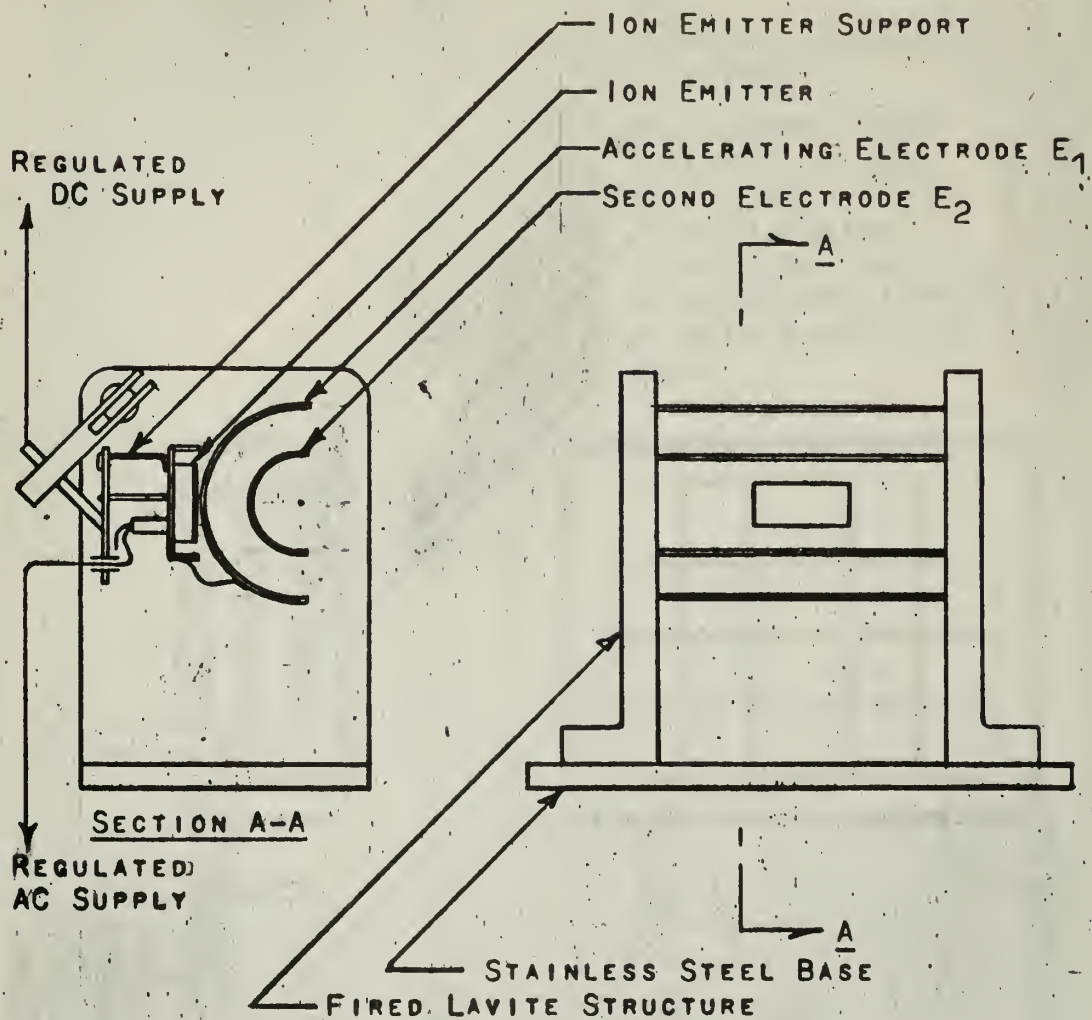
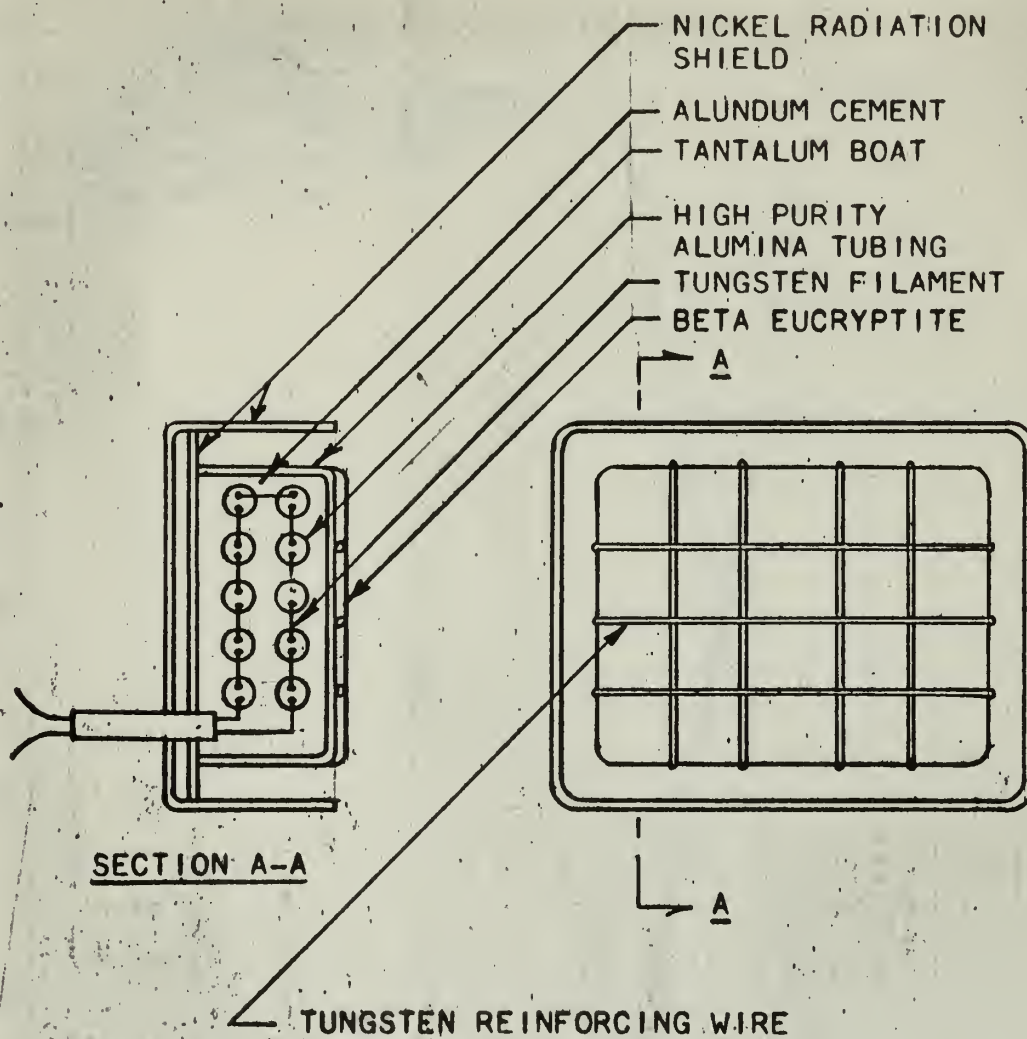


FIGURE 4

LITHIUM ION EMITTER



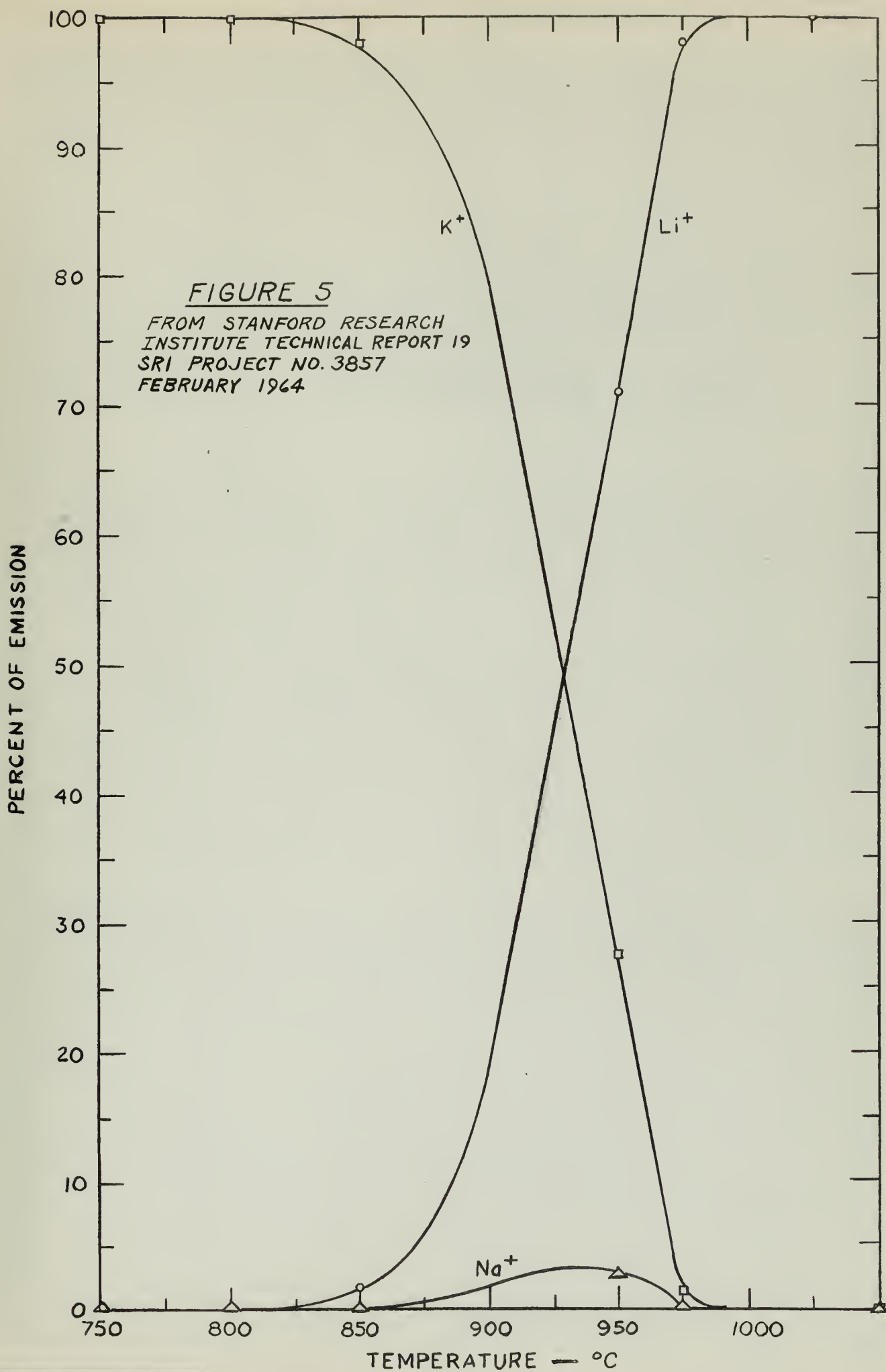


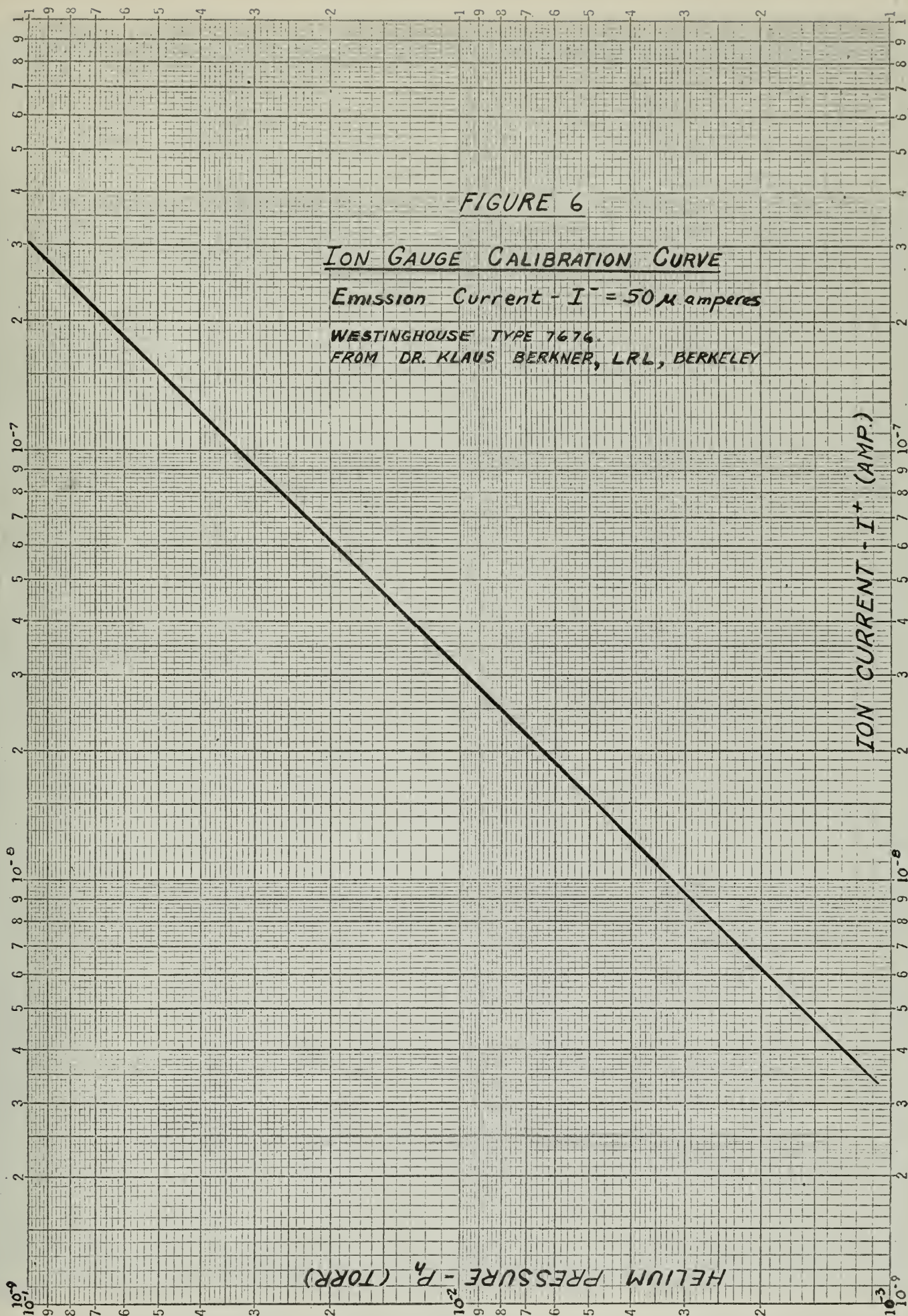
FIGURE 6

ION GAUGE CALIBRATION CURVE

Emission Current - $I^- = 50 \mu$ amperes

WESTINGHOUSE TYPE 7676

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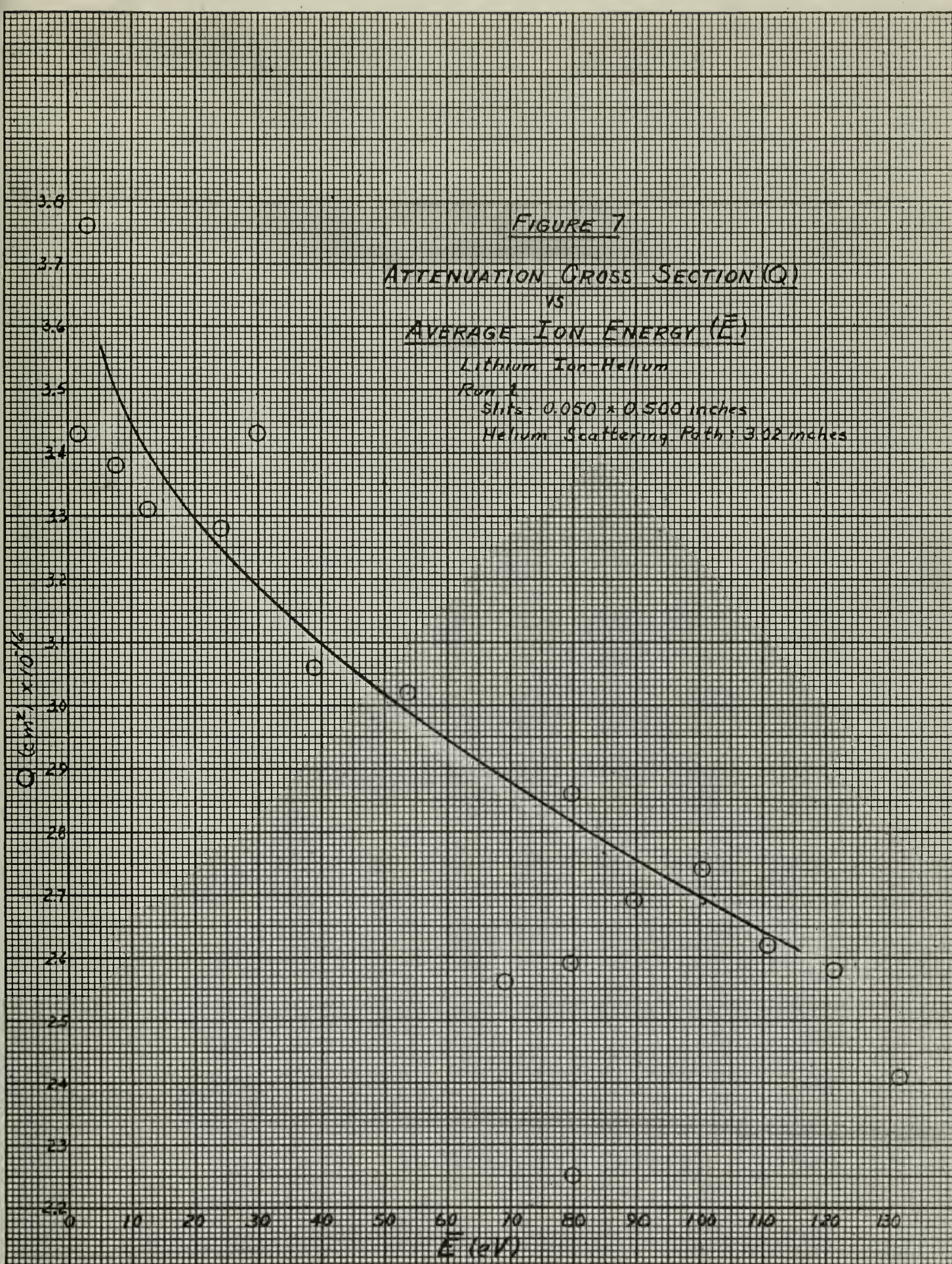


FIGURE 7

ATTENUATION CROSS SECTION (Q)

VS

AVERAGE ION ENERGY ($\bar{E}$)

Lithium Ion-Helium

Run 1

Slits: 0.050×0.500 inches

Helium Scattering Path: 3.02 inches

FIGURE 8

ATTENUATION CROSS SECTION (Q)
VS

AVERAGE ION ENERGY ($\bar{E}$)

Lithium Ion - Helium

Run 2

Slits: 0.025 x 0.500 inches

Helium Scattering Path: 3.02 inches

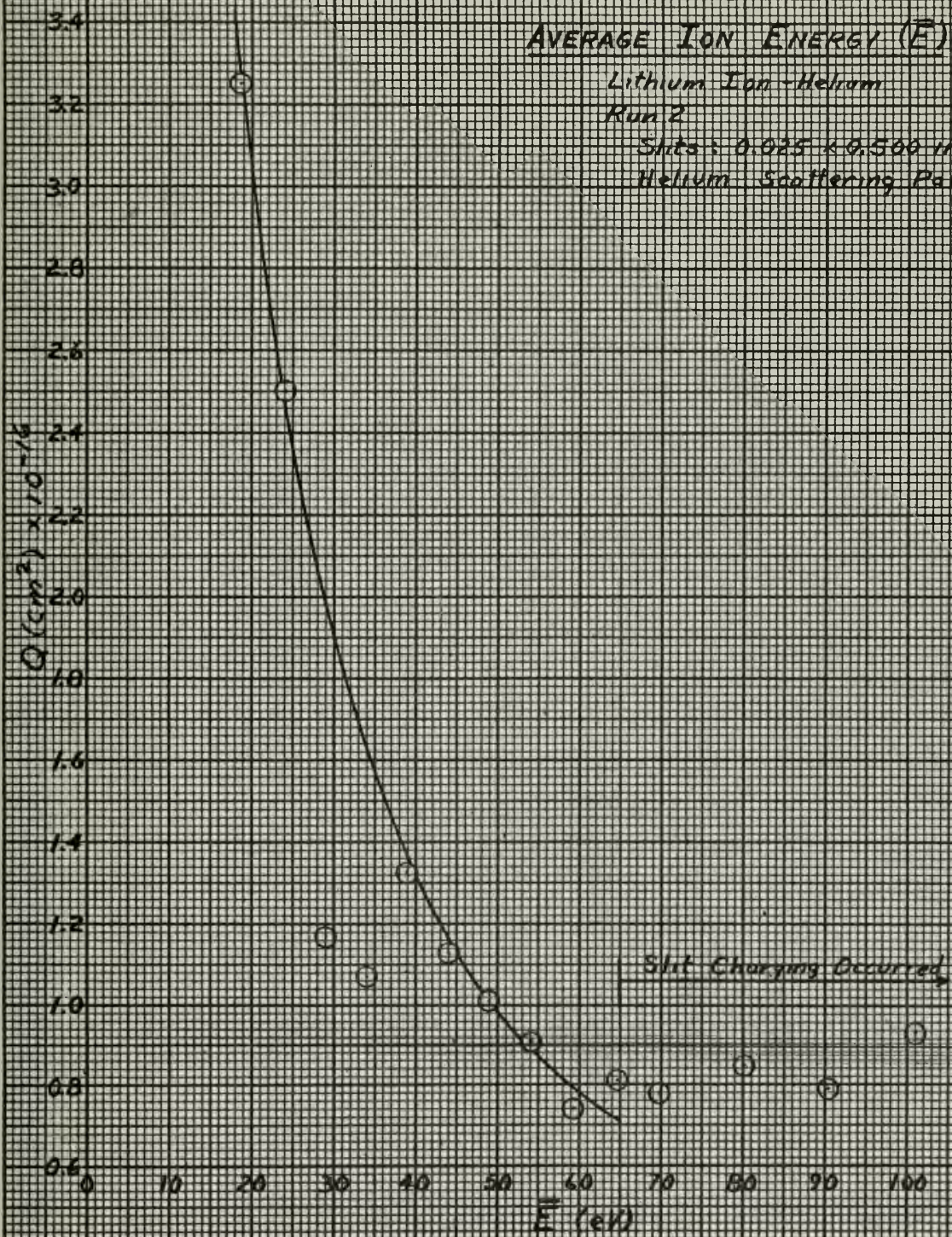
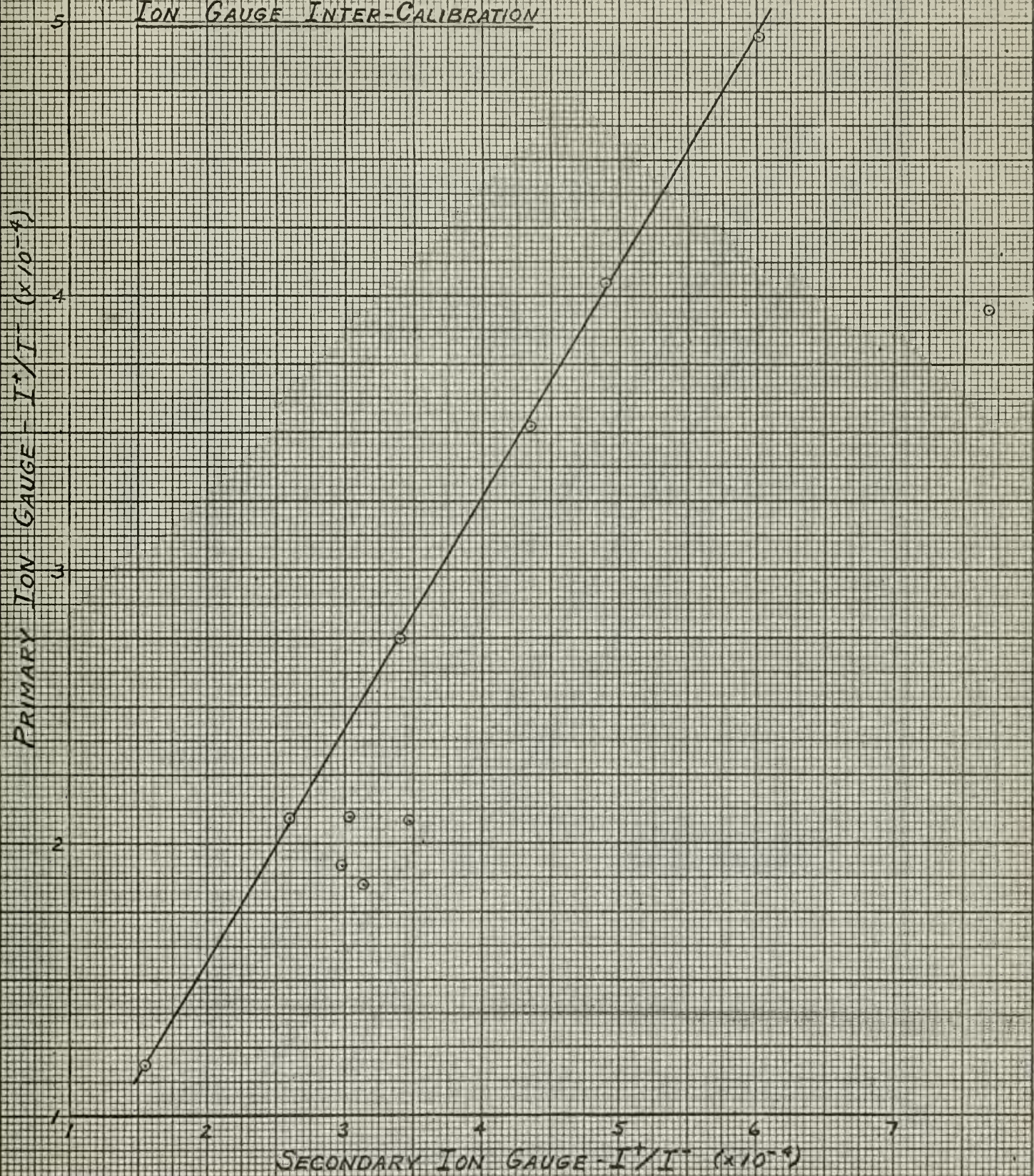
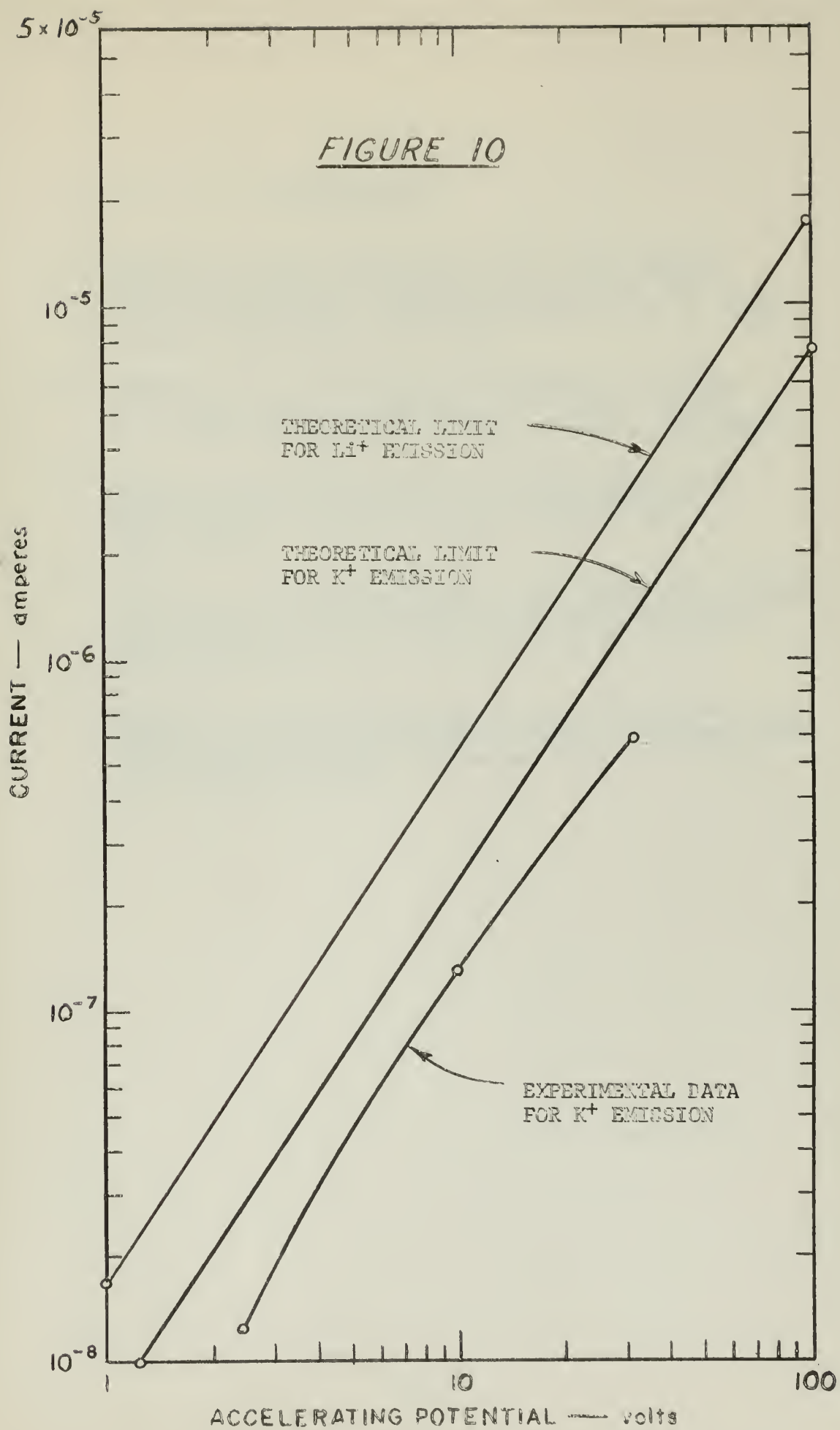


FIGURE 9

ION GAUGE INTER-CALIBRATION





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3. Amdur, I. and Harkness, A. L.; Scattering of High-Velocity Neutral Particles, II. Helium-Helium; The Journal of Chemical Physics, Vol. 22, No. 4, April, 1952.
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APPENDIX

A. LITHIUM ION BEAM SOURCE

The ion source (see figure 3) consists of a thermal Lithium ion emitter and an ion gun, which supports the emitter, forms a fairly uniform intensity ion beam and directs it toward the beam collimator with the desired energy.

The ion emitting material is high purity beta eucryptite ($\text{Li}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$) of a very fine granular form. It is suspended in a vehicle of amyl acetate and Parlodion, a non-explosive nitro cellulose. This suspension is painted onto the prepared face of a heater unit. (see figure 4). The heater unit consists of: (1) .007 inch tungsten wire filament, wound through two hole, high purity, alumina tubing, (2) a tantalum boat into which the filament unit is assembled by embedding it in alundum cement and (3) nickel support structure and thermal radiation shield. Prior to assembly, the inside of the tantalum boat is coated with alundum cement for electrical insulation and the exterior face is scribed and tungsten wire spot welded across the face in both directions to provide better adherence of the beta eucryptite suspension. The filament is powered by a regulated AC supply as shown in figure 1B. It was necessary to isolate the variable AC control from the circuit after emitter heat-up to minimize ion beam fluctuations. The Lithium ion emitter, as shown in figure 4, less the outer radiation shield, was developed by the Stanford Research Institute. Figure 10 gives the theoretical Lithium ion emission limit for a parallel plate geometry.

APPENDIX (Cont'd)

The ion gun (see figure 3), aside from the emitter support structure, consists of two stainless steel cylindrical electrodes with central apertures for beam passage. The electrodes are held in place by heat resistant, electrically insulating supports, of fired lavite material. The desired accelerating potential is applied to the emitter structure and to the nearest electrode which accelerates the ions and forms them into a convergent beam. The design of the electrodes is based on the Pierce principle of focusing space charged limited beams of charged particles. The accelerating potential is applied by a Keithley 240, regulated D.C. supply which maintains discrete potentials to +0.1% above 5 volts.

Reference 2 gives detailed characteristics and specifications for the emitter and gun assembly.

APPENDIX

B. BEAM COLLIMATING AND SCATTERING UNIT

The broad beam from the Lithium ion source is defined to a narrow one and collimated by slits S_1 and S_2 of the beam collimating and scattering unit (see figure 1A). These slits and the aperture slit (S_3) are formed and aligned by butting gold plated, stainless steel razor blades against the bottom and sides of a supported, flat ground bar of .500 inch (1.27 cm.) width, and spot welding them to the slit frame structure. The top portion of each slit is installed by butting a blade from above against the desired thickness gauge and spot welding it to the frame. A mask of nickel sheet is installed to cover the entraneous openings. The slit frames are held at ground potential (see figure 1B). Slit blades are gold plated to minimized surface charging.

The scattering chamber is electrically isolated from the second slit frame by sheet teflon, so that the portion of the beam intercepted by the second slit frame can be measured. This measurement is used to correct ion collector current measurements for changes in incident beam current during a measurement. The scattering chamber (see figure 1A) is an enclosed region, except for slit openings. It is provided with a scientific grade Helium supply. The Helium is taken through a liquid air cooled trap, a manual metering valve, and stainless steel and teflon tubing to the scattering chamber.

APPENDIX (Cont'd)

A chamber port with closure is provided to hasten Helium pump out after each set of measurements. Another port admits the background gas and the Helium plus background gas pressures in the scattering chamber to a Westinghouse WL 7903 high pressure ion gauge for measurement. The ion gauge ion current (I^+) is measured with a Keithley 410 micro-micro ammeter while the electron collector current (I^-) is measured by a standard 0 - 50 micro ammeter (see figure 1B). The ion gauge control circuit provides an adjustable, regulated AC voltage across the gauge filament and regulated DC bias potentials of 60 and 120 volts to the ion gauge filament and electron collector, respectively. The control circuit is similar to the one specified in the Westinghouse ion gauge operating instructions. In the absence of a current regulated filament supply it was necessary to introduce a 1500 watt lamp, as shown in figure 1B, to stabilize ion and electron current readings.

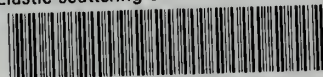
The unscattered portion of the Lithium ion beam is collected on a large flat plate (C) behind the aperture slit (S_3), (see figure 1B). The ion beam current is measured with a second Keithley 410 micro-micro ammeter, which can be switched to measure the portion of the beam intercepted at slit frame, S_2 . A grid of high transparency is located between the aperture slit

APPENDIX (Cont'd)

(S₃) and the Lithium ion collector (C) and is held at about negative 40 volts to suppress secondary electron emission from the collector. A grounded shroud surrounds the collector and of the unit to shield it from stray ion collection. The components of the unit are mounted on an unfired, lavite base. Shielded cables carry currents to be measured from Kovar conductors at the wall of the vacuum chamber to the measuring instruments.

thesE114

Elastic scattering of 1-100eV lithium io



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